1923

BULLETIN No. 274 MAY, 1923

Guilliman Baker

PRUNING YOUNG APPLE TREES

IMPERIAL BUREAU OF MYCOLOGY
17 MAY 1924

Seven-year-old Grimes apple trees. From left to right, the trees have received light, medium and heavy pruning. The tree at the left is larger and has produced more fruit to date than either of the other two.

PURDUE UNIVERSITY
AGRICULTURAL EXPERIMENT STATION
LAFAYETTE, INDIANA.

Fruit growers naturally are interested in growing trees that will come into bearing early and have mechanical strength for supporting a full crop of fruit. It has been a common practice among growers to head back young trees during the first four or five years, to make the tree "stocky." The results of experiments in apple pruning carried on at this station, show that a strong tree can be grown with little heading back after the first year.

Annual heading back reduces the size of the tree. Pruning reduces the leaf surface of the young tree, by removing a large number of active buds and growing points that would open into foliage. The immediate result of cutting back a tree is increased growth from the pruned branches. However, the total growth produced is usually less than that of an unpruned tree, and the tree is dwarfed by the pruning. When top growth is reduced, root growth is also reduced. The pruned tree is thus smaller in root and top than the tree which has not been pruned.

Pruning in the young tree should be largely corrective in nature, for the removal of a large amount of wood will dwarf the tree and reduce early fruitfulness.

Some pruning on the young tree will be necessary in training and directing the growth of the branches. This early pruning is essentially a training process and not for the purpose of increasing growth. It is a safe practice to prune the young tree at planting time. Select branches that are well spaced on the trunk to form the head. Allow the small branches to grow from these, even though the young tree may look quite dense. The first fruits on some varieties are borne on these branches.

Strong, upright growing shoots in the tree, which compete with the leader or scaffold branches should be removed. A general heading back should be avoided after the first year. However, if conditions favor a very long shoot growth, heading back will help to cause branching lower down on the shoot. Avoid weak crotches, by unequal cutting of branches. The branch receiving the heaviest cutting will make the least growth.

PRUNING YOUNG APPLE TREES

F. P. Cullinan Clarence E. Baker

Realizing the need among Indiana fruit growers for information on the question of the kind and amount of pruning required for the successful development of a young orchard, experiments on the pruning of young apple trees were begun by this station in 1912. This work was started in a commercial orchard at Laurel, Indiana, and consisted, in the main, of a study of the growth and development of young apple trees receiving varying degrees of pruning. The trees were pruned to the open head and central leader types.

In 1916 another experiment was begun at Bedford, Indiana, where trees receiving the same pruning treatments were grown in cultivation and sod. In this case the top treatment was varied as well as the cultural treatment. It was apparent at this time that other measurements of tree growth, than girth and production, should be taken if the factors responsible for this growth and production were to be discovered. Hence in 1917, an experiment providing for a more careful study of the pruning problem was begun at LaFayette, Indiana. The object of this experiment, broadly speaking, was to study the response of the tree to systematic, annual, dormant pruning and to determine those factors causing this response or associated with it. It is with this later experiment that most of the data presented in this bulletin are concerned.

These pruning experiments were started by Professor Joseph Oskamp, formerly of this station. To him much credit is due for the planning of the experiments, planting of the trees and the collection of much data reported herein.

PLAN OF THE EXPERIMENT

In the spring of 1917, 286 two-year-old apple trees were planted at LaFayette in a block of 13 rows. The trees were set 15 feet apart each way and each row contained 22 trees. The trees were set close at the beginning of the experiment since all trees in alternate rows were to be removed in later years for study. The variety used was Grimes. It was chosen because it is at the present time the leading commercial variety in Indiana, and it is not as susceptible to blight in this climate as some other varieties. This last consideration is of importance in choosing a variety for pruning studies. At the time of planting the trees were selected for uniformity in size and vigor as judged by caliper of trunk and the growth made the previous season. These were distributed in the plots so as to give uniformity for all plots.

The thirteen plots included in the experiment were treated as follows:

Plot I—Buffer, no pruning.
Plot II—No pruning.
Plot III—Root pruning at planting time, no top pruning.
Plot IV—Root and top pruning at planting time.
Plot V—Cutting back and thinning.
Plot VI—Corrective.
Plot VII—No pruning.
Plot VIII—Thinning.
Plot IX—Cutting back or clipping.
Plot X—Partial or individual limb pruning.
Plot XI—Pruning in alternate years.
Plot XII—No pruning.
Plot XIII—Buffer, no pruning.

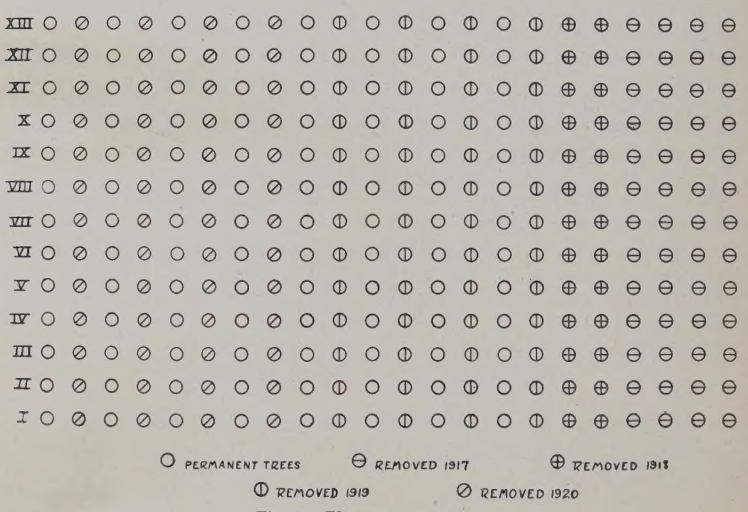

Fig. 1. Plot arrangement.

The two outside rows I and XIII were established as buffer rows (Fig. 1) to eliminate any influence which might accrue to these rows which are under conditions of exposure somewhat different from rows inside the plot. These trees have been treated identically like the unpruned trees. At the time of planting no root pruning was given to any of the trees, except those in row IV, which were included for the purpose of studying the responses of a tree following root pruning in conjunction with top pruning. Rows III and IV are to be considered in this connection only and are really not a part of the main pruning experiment.

Plots II, VII and XII, the unpruned rows, received no pruning at planting time or during the time of the experiment. (See Fig. 2 C.)

Plot V. The pruning given this plot consisted in cutting back all branches which were crowding or might crowd in the near future and cutting back the annual growth one-half to two-thirds. (See Fig. 2 A.) After the first year the pruning consisted of cutting back the annual growth one-third to one-half and removing shoots that were crowding. While this row is one of the most heavily pruned rows, it has not been pruned more severely than is frequently practiced by growers in pruning trees of this age.

Plot VI. Corrective pruning. This treatment at planting consisted in removing crowded branches, and cutting back the two or three laterals, which were left for scaffold limbs, one-fourth to one-third. (See Fig. 2 B.) In succeeding years the terminal growth was lightly cut back to subordinate the growth of scaffold limbs to the central leader and where necessary to shape and direct the growth of the branches. Light thinning out was given where branches rubbed. The pruning during the fifth and sixth years, which is reported in this experiment, was very light. This has been called corrective pruning since the removal of portions of the top was done with the view of properly shaping the tree and directing the growth of the branches. No systematic cutting back was given after the first year.

Plot VIII. The trees in this row have received thinning of the branches only. A central leader was left and two or three well spaced branches were selected for scaffold limbs. No cutting back of any of the branches was given during the first or succeeding years.

Plot IX. The trees in this block received cutting back or clipping only. At planting time all healthy limbs which were on the trees as they came from the nursery were retained. These were severely cut back leaving a central limb longer than the rest of the branches. The pruning given after the first year was to cut back all annual growth one-half to two-thirds. No thinning was done. In severity of pruning this row would compare with row V. with the exception that no branches had been thinned out.

Plot X. The trees in this row were included for special study of partial pruning. Four limbs of as nearly uniform size and vigor as possible were selected and all the other growth was cut away. In addition a central leader was left. Of the limbs retained, two were severely cut back and two were left unpruned.

Plot XI. Alternate pruning. The treatment consisted in pruning the trees every other year. During the first year of the experiment the trees were left unpruned. In the alternate year they were given a corrective pruning. This consisted of cutting back branches slightly to permit the main scaffold branches to

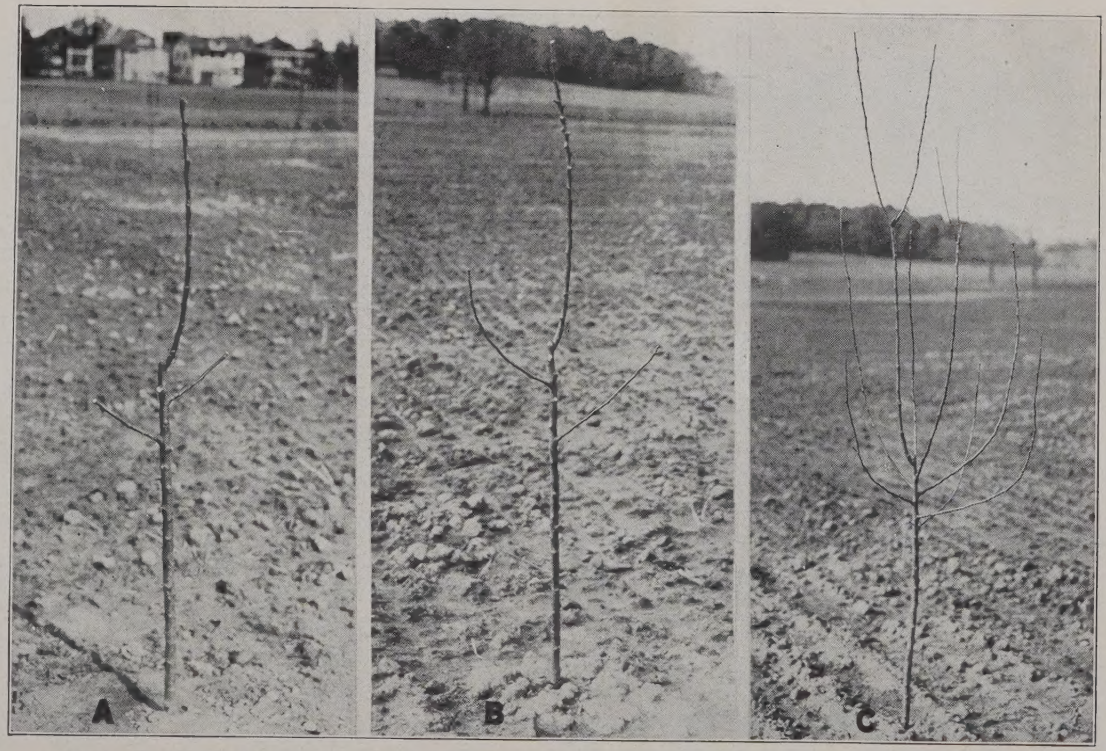

Fig. 2. These trees illustrate the varying amount and kind of pruning given at the beginning of the experiment:
(A) Cut back and thinned out.
(B) "Corrective"—light cutting back and thinning.
(C) No pruning.

predominate, and thinning out where there was serious crowding.

In this investigation all pruned trees were trained to a central leader type of tree. The investigation deals with a study of responses in growth following the removal of varying amounts of wood from the top of the tree trained to one system and does not involve a comparison of different systems of training. Later on in this bulletin data will be presented from the results of other experiments showing the growth and fruitfulness of trees trained to different systems. The pruning consisted of dormant pruning only.

Soil Treatment

The soil in the station orchard at LaFayette, where these trees were planted, is a silt loam. The subsoil at a depth of about 18 inches is of heavy gravel. It is not an ideal orchard subsoil when considered from the standpoint of water retention. In dry seasons the moisture is lost rapidly from this soil.

The soil treatment given the trees during the experiment has been uniformly the same for all plots. Cultivation with cover crop has mainly been the cultural practice given. Briefly the cultural treatments were as follows: The cover crop was disked under in the spring and the plots were harrowed three or four times during the summer. A cover crop was sowed about August 1st. During the first year cabbage was planted as an intercrop and rye was the cover used. Millet was the cover crop used in all succeeding years. In 1920, however, the orchard was not cultivated but was left in a natural seeding of grass. In the late fall of 1919 the plots were given an applicatlon of manure, uniformly applied to the entire area at the rate of about 10 tons per acre. No commercial fertilizers were used on the cover crops or applied to the plots for the benefit of the trees.

DATA SECURED

In attempting to study the effects of the removal of varying amounts of wood from the young trees and to measure the response in growth, it was felt that this could be more accurately done by removing a number of trees from each plot during the first three or four years of growth and weighing the entire tree. In this way it should be possible to obtain a quantitative measure of the new tissues laid down each year By this means not only could the total weight of trees be obtained, but the effects of pruning on the growth of top and root system could also be studied by measurement. The following data were secured:

1. At the time of planting, the trees were weighed in bundles of ten and the average weight of each tree planted was determined. This gave information on the uniformity of the trees for the various plots

2 The prunings removed from the trees in each plot were weighed after the annual dormant pruning.

3. The trunk circumference of each tree was measured annually at a marked point on the trunk about one foot above the ground.

4. A certain number of trees were removed annually during the first four years from each plot at the end of the growing season. Data were secured on the weight of roots, top and annual growth. The trees were carefully dug and the dirt shaken from the roots. Broken roots were searched out of the soil and weighed.

5. Leaf counts were made on representative trees in each plot and the total leaf surface calculated from the measured areas of individual leaves. Measurements were made with a planimeter.

6. Fruit spur and blossom bud counts were made.

7. The fruit from each tree was weighed and counted.

8. Phenological and meteorological records were kept.

9. Photographs showing the relative size of the trees were taken each year before and after pruning.

The plan of this experiment was to dig a certain number of trees each year and study the effects of the pruning on the tree as a whole, in a manner which could not be done unless the trees were removed from the soil. This involved weighing the roots and the top. Trees were removed over a period of four years. Owing to the manifest changes in size of trees each year, the results on tree weights and the growth behavior of the trees are presented separately for each season.

THE FIRST SEASON—GROWTH OF 1917

At the close of the first growing season four rows of trees running across all plots were dug and the trees were weighed. In some cases trees had to be discarded because of mechanical injuries received or because of outside influences which were not a part of the pruning treatment. This left a total of 14 unpruned and 12 pruned trees on which data were taken. The data on the weight of the tree parts are given in Table I. These data presented for the first year after planting, cover the period when the trees were adjusting themselves to the new environment and are of interest, when considered from that standpoint. They are also suggestive of facts which are more conclusively proven in tables that are to follow.

THE EFFECTS OF ROOT AND TOP PRUNING AT PLANTING TIME

The trees which had heavy root pruning but no top pruning were seriously handicapped in adjusting themselves to the new environment. Seventy per cent of the trees receiving this treatment died during the first summer. On the contrary it is of interest to note that other trees which had similar top treatment (no pruning), but no root pruning, survived as well as trees that were cut back. In the first summer four of the 122 trees which

TABLE I.—AVERAGE WEIGHT OF TREES DUG AT CLOSE OF FIRST GROWING SEASON 1917

Row	Treatment	No. Trees	Wt. of entire tree in lb.	Wt. of roots in lb.	Wt. of top in lb.	Wt. of one yr. wood in oz.	Wt. of prunings removed in oz.*	Circumference gain in in.*
II	No pruning	3	2.38	.99	1.39	.39	-----	.32
IV	Root and top pruning	3	1.12	.459	.653	.84	5.96	.27
V	Cutting back and thinning	4	1.58	.79	.80	1.76	5.92	.35
VI	Corrective	3	1.55	.78	.77	.74	4.32	.33
VII	No pruning	3	2.25	.93	1.32	.21	-----	.39
VIII	Thinning	2	1.94	.91	1.03	.60	4.70	.25
IX	Cutting back	3	1.45	.64	.80	.95	3.92	.24
XI	Alternate	4	1.97	.79	1.18	.17	-----	.26
XII	No pruning	4	2.07	.85	1.22	.32	-----	.21

*Average of 16 trees per plot.

had no root or top pruning died while three of the 110 trees which had top pruning, but no root pruning, died. Another interesting feature of the first years results was the growth made by trees which had heavy root pruning and a correspondingly heavy cutting back of the top. These trees made a fair length growth the first year although when measured by total weight, the trees were smaller at the end of the first season than any of the other trees in the experiment. Most of the trees, however, which received this root and top pruning lived, while nearly three-fourths of those receiving root pruning with no top pruning died. It is probable on such experiences that heavy top pruning of young apple trees has been rather widely recommended. However, from the results secured in this work, it appears that pruning of the root at planting time lessens the ability of the tree to support growth, through its reduced root system. If no more root pruning is given than that which necessarily results from digging the tree in the nursery, the trees will make satisfactory length growth, when transplanted to the orchard. In the spring of 1916 trees planted at Bedford, Indiana, and given no root pruning made greater length growth than trees which had the roots pruned at planting. Pickering (2) in working with dwarf trees in England found that heavy root pruning checked the growth of the trees.

The individual shoot growths on the pruned trees were longer and heavier than shoots from unpruned trees (Fig. 3). The rainfall during the first season was about normal for May and June. July was very dry, being 2.36 inches below normal. August was about normal and September was about 1.85 inches below normal. Therefore, it would be expected that the tree with the largest leaf surface, which was slow in adapting itself

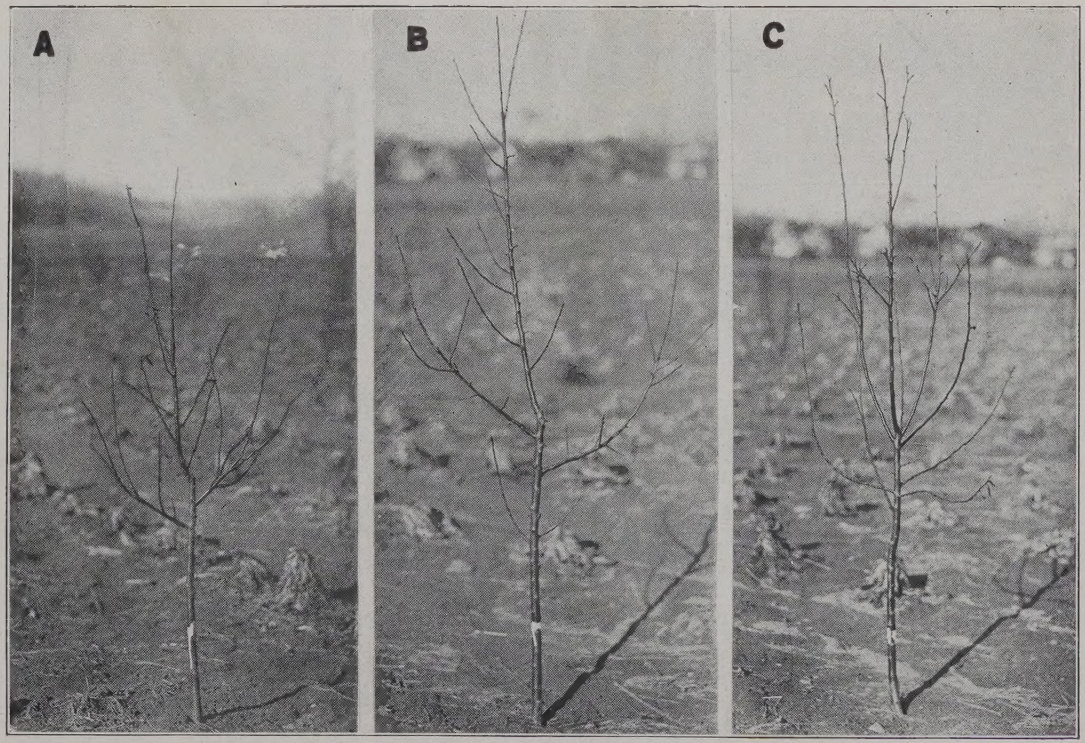

Fig. 3. The first season's growth.
(A) Cut back and thinned out.
(B) "Corrective" pruning.
(C) No pruning.
Note the longer terminal growth made on (A) and the shorter growth on (C).

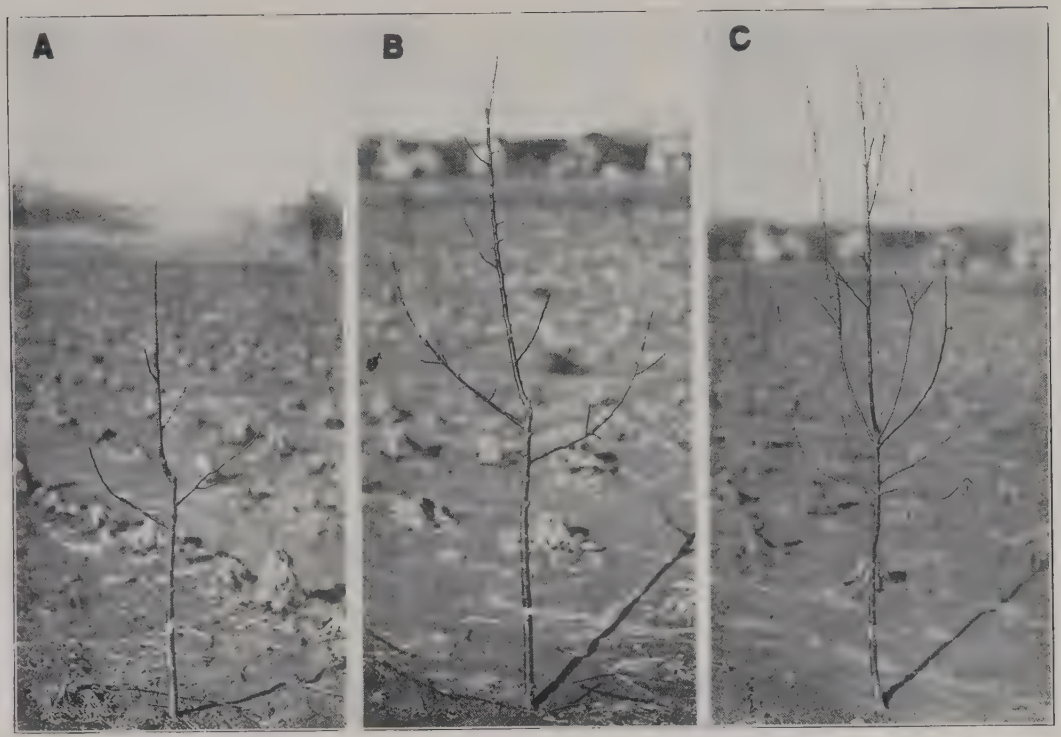

Fig. 4. The trees shown on the opposite page, after pruning, at the beginning of the second year. (Compare these same trees under these systems of pruning in succeeding years. Figures 5, 6, 8, 9 and 11.)

to the soil would, under such conditions, suffer more than trees which had their leaf surface reduced by pruning. Yet, despite the poor growth made by these unpruned trees they were heavier than the pruned trees at the close of the growing season. The growth made during the first season by the more heavily pruned trees did not equal the amount cut off at planting time.

It will be seen further, from Table 1, that unpruned trees dug at the close of the first growing season possessed a heavier root system than trees which had been cut back. However. it is not inferred from this data that trees should not be cut back at planting time. In view of the general practice among growers and the likelihood of securing some trees from the nursery with a greatly reduced root system, it would appear to be a safe practice to do some cutting back at planting time to balance the top with the root system. Before discussing further the results secured during the first season the data on weights of trees dug in the following years will be presented, since they reflect the effects of the first year's treatments.

THE SECOND SEASON—GROWTH OF 1918

At the close of the second growing season two trees were dug from each row running across the plots. This made two trees from each plot or a total of ten pruned and six unpruned trees. While this is not a large number of trees, those dug were as uniform as any remaining in the plots. The data appear in Table II. It will be seen from the weights of root and top that the unpruned trees are the larger. The trees which had received no pruning for the two years they were in the orchard averaged about 28% heavier in total weight than the pruned trees. (The

TABLE II.—AVERAGE WEIGHT OF TREES DUG AT CLOSE OF SECOND GROWING SEASON 1918

Row	Treatment	No. Trees	Wt. of entire tree in lb.	Wt. of roots in lb.	Wt. of top in lb.	Wt. of one yr. wood in oz.	Wt. of prunings removed in oz.*	Circumference gain in in.*
II	No pruning	2	5.18	1.77	3.41	7.90	----	1.02
V	Cutting back and thinning	2	4.29	1.55	2.74	13.72	1.76	.70
VI	Corrective	2	3.43	1.15	2.28	8.64	.66	.78
VII	No pruning	2	4.79	1.85	2.94	7.55	-----	.98
VIII	Thinning	2	4.01	1.44	2.57	7.27	.32	.47
IX	Cutting back	2	2.36	1.00	1.36	3.95	.64	.74
XI	Alternate	2	4.29	1.63	2.66	10.23	6.08	.78
XII	No pruning	2	5.52	1.96	3.56	9.52	----	.94

*Average of 16 trees per plot.

trees in row IX which had heavy cutting back were noticeably smaller than those having a similar treatment and are not included in the above percentage difference.) The roots of the unpruned trees averaged 29% heavier than those of the pruned trees, and the tops averaged 29% heavier than the tops of pruned trees. Those trees which are the heaviest have also made the greatest gain in trunk growth. However, the trees which were heavily cut back (again excluding row IX) have made the greatest terminal growth. The response in growth following heavy cutting back is manifested by an increase in amount of terminal growth and from this standpoint the pruning has had an invigorating effect on growth near the points where the cuts were made. Yet if we consider the tree as a whole, it has been dwarfed in size. Not only has the top of the tree been reduced by heavy pruning, but the root system has also been correspondingly reduced.

THE THIRD SEASON—GROWTH OF 1919

During the third year the trees were in the orchard, a difference in the relative size of the trees under different pruning treatments was beginning to be apparent (Fig. 5). Four trees were dug from each plot at the close of the third growing season and weighed as in previous seasons. The data for the year are presented in Table III. At this time those trees which had no pruning (Rows II, VII and XII) averaged 76% heavier than trees which were heavily pruned (Rows V and IX), and 48% heavier than trees which were given a moderately heavy pruning (Rows VI, VIII and XI).

While these percentage differences are subject to a probable error in individual tree weights, the fact remains that the unpruned trees were the heavier in root and top weights. Furthermore, if we compare the weights of the smallest of the unpruned trees that were dug (Row II), with the weights of the heaviest of the more severely pruned trees (Row IX), we find that the roots of the unpruned trees are over 19% heavier and the tops 9% heavier than the pruned trees (Fig. 7).

TABLE III.—AVERAGE WEIGHTS OF TREES AT CLOSE OF THIRD GROWING SEASON 1919

Row	Treatment	No. Trees	Wt. of entire tree in lb.	Wt. of roots in lb.	Wt. of top in lb.	Wt. of one yr. wood in oz.	Wt. of prunings removed in oz.	Circumference gain in in.
II	No pruning	4	11.46	4.17	7.29	28.5	---	1.79
V	Cutting back and thinning	4	7.82	2.90	4.92	23.7	7.8	1.00
VI	Corrective	4	10.34	3.67	6.67	28.6	3.8	1.44
VII	No pruning	4	17.78	6.64	11.14	39.5	---	1.72
VIII	Thinning	4	9.12	3.14	5.98	23.0	2.3	1.68
IX	Cutting back	4	8.74	3.49	5.25	27.5	3.9	1.12
XI	Alternate	4	9.88	3.45	6.43	25.4	---	1.33
XII	No pruning	4	14.33	5.57	8.76	38.9	---	1.48

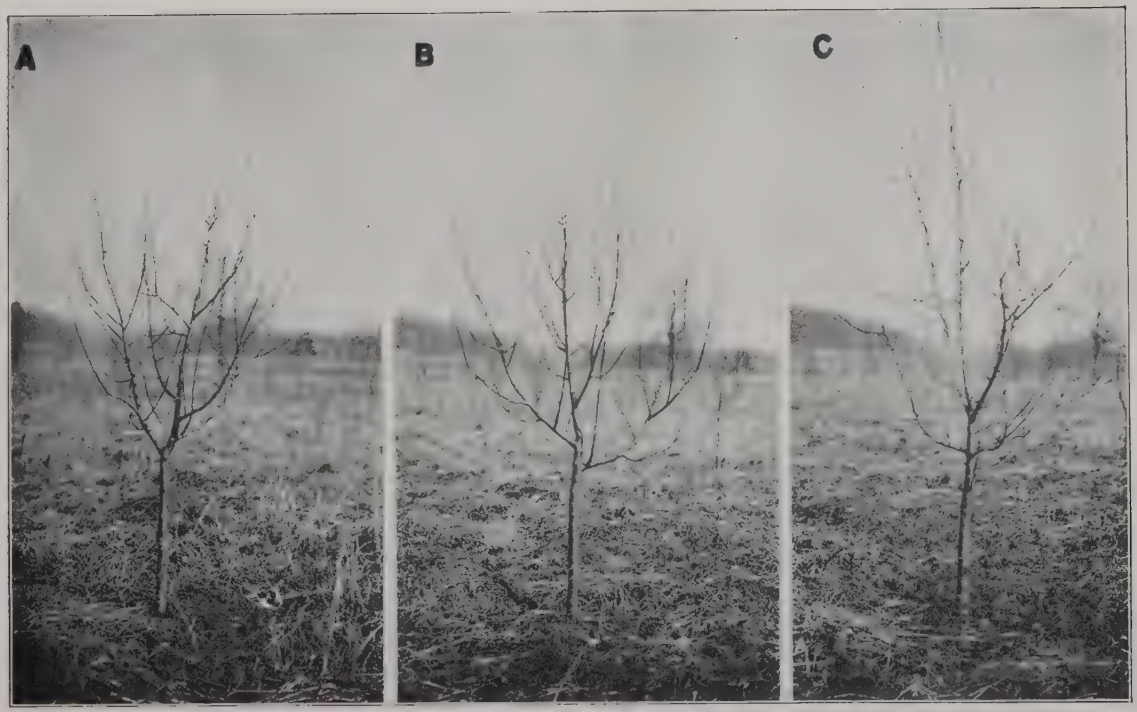

Fig. 5. The trees shown in Figure 4 at the end of third year. At this time lightly pruned trees (B) and (C) are making a greater total terminal growth than (A). The unpruned trees (C) are about 75 per cent heavier than (A) and 48 per cent heavier than (B)

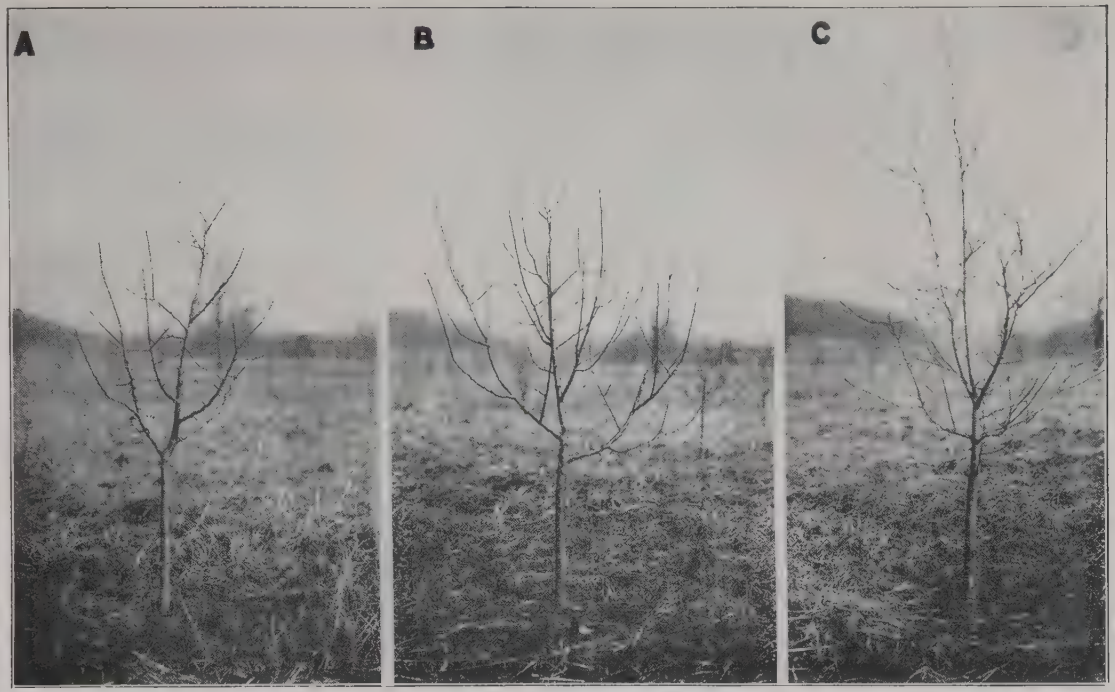

Fig. 6. The trees shown in Figure 5, on opposite page, after pruning, at beginning of fourth year. Note that (B) at this time has been given very little heading back.

Apart from root and top weights, the weight of terminal growth is interesting. In the first two years of this experiment, the pruned trees produced more terminal growth as measured by length and weight of the wood produced. In the third season we find that the unpruned trees have produced more terminal wood than pruned trees. The lightly pruned trees have also produced about as large an amount of this type of growth. Alderman and Auchter (1) in their experiments in pruning young apple trees have had similar results and state that the heavily pruned trees produced as much as, or slightly more growth, than did the lightly pruned trees for the first two years. The trees that were not cut back have, in this experiment, recovered from the shock of transplanting and the failure to cut back at planting time has apparently had no harmful influence on the growth in the succeeding years.

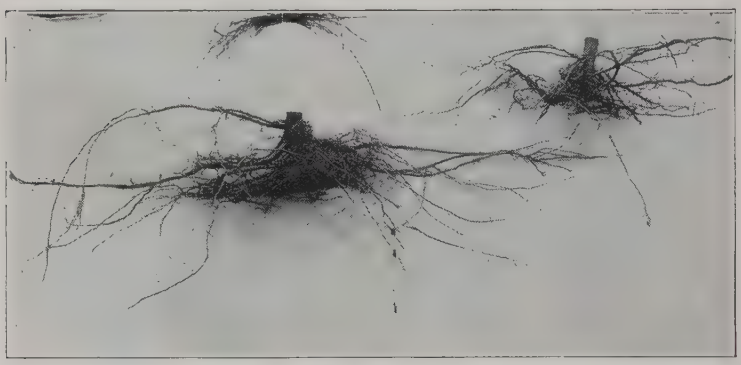

Fig. 7. The root systems of representative trees three years old. Left—no pruning. Right—cutback and thinned out. Heavy pruning for three years has reduced the weight of the roots 41 per cent.

THE FOURTH SEASON—GROWTH OF 1920

At the close of the fourth growing season the remainder of the trees in the alternate rows were removed and weighed. The number of trees per plot on which we have data is not as great as in the previous season, since some of the trees had to be discarded. We find after the trees have been in the orchard for four seasons (Table IV) that unpruned trees continue to show increased total weight over heavily pruned trees. The results are in accord with those secured during the previous season. The eleven unpruned trees (Rows II, VII and XII) averaged about 24% heavier than eight lightly pruned trees (Rows VI, VIII and XI) and 35% heavier than five heavily pruned trees (Rows V and IX). It can readily be seen that the unpruned trees are much larger after four years. The dwarfing effect of the pruning is illustrated in Fig. 8.

The data presented in Tables I to IV which cover the first four years of the life of the young trees, show that any amount of pruning has reduced the size of the tree. Not only has the top of the tree been reduced, but the root system has also been correspondingly reduced. During the first two years, if the weight of one year wood is taken as a measure of vigor, we might conclude that pruning is an invigorating process. This is true when we consider the effect on the one-year terminal growth of young trees. The response in growth is mainly near the point where the cut was made and this growth is usually longer and heavier than that arising from branches not cut back. However, we must also consider the effect the pruning has on the tree as a whole.

TABLE IV.—AVERAGE WEIGHT OF TREES DUG AT CLOSE OF FOURTH GROWING SEASON 1920

Row	Treatment	No. Trees	Wt. of entire tree in lb.	Wt. of roots in lb.	Wt. of top in lb.	Wt. of one yr. wood in oz.	Wt. of prunings removed in oz.	Circumference gain in in.
II	No pruning	3	25.12	10.19	14.93	14.9	---	1.51
V	Cutting back and thinning	2	16.19	6.42	9.77	15.8	7.5	1.18
VI	Corrective	2	17.70	6.12	11.58	20.5	3.3	1.62
VII	No pruning	4	20.65	9.02	11.63	16.3	---	1.56
VIII	Thinning	3	19.55	9.12	10.43	13.8	2.1	1.60
IX	Cutting back	3	17.80	7.24	10.56	15.8	4.6	1.22
XI	Alternate	3	17.78	6.92	10.86	14.4	3.8	1.56
XII	No pruning	4	23.21	9.54	13.67	18.7	---	1.46

In Table V the weight of one-year wood cut from the trees dug each year is given, and in Table VI the weight of wood older than one year on the same trees is given. Taking two rows of trees, II and V, that have had quite different pruning treatments, and comparing them in each of these tables, the figures show the effects of pruning on the growth of the top of the tree. It will be noted that during the first and second year (Table V), heavy cutting back has increased the weight of terminal growth very markedly over trees not cut back. In the third and fourth years, the weight of terminal wood was just as great on trees that had not been pruned. In the case of wood older than one year, the figures are interesting because it is from wood of this age that a very large per cent of the fruit buds of the apple are borne. Again comparing Rows II and V (Table VI) the wood older than one year in the tops of the unpruned trees in the first season was 99% heavier than that in trees heavily cut back, in the second year 55% heavier, in the third 60% heavier, in the fourth 42% heavier. Thus at the end of four years those trees which were

TABLE V.—THE EFFECT OF PRUNING ON GROWTH OF ONE-YEAR WOOD

Plot	Treatment	Average weight of 1 yr. wood in ounces per tree			
		1917	1918	1919	1920
II	No pruning	.387	7.90	28.48	14.88
V	Cutting back and thinning	1.76	13.72	23.68	15.84
VI	Corrective	.741	8.64	28.54	20.53
VII	No pruning	.212	7.55	39.47	16.29
VIII	Thinning	.599	7.27	23.14	13.80
IX	Cutting back	.946	-----	27.51	15.84
XI	Alternate (pruned '18 and '20)	.176	10.23	25.42	14.43
XII	No pruning	.317	9.52	38.88	18.72

TABLE VI.—THE EFFECT OF PRUNING ON GROWTH OF WOOD OLDER THAN ONE YEAR

Plot	Treatment	Average weight of old wood in pounds per tree			
		1917	1918	1919	1920
II	No pruning	1.367	2.914	5.507	13.997
V	Cutting back and thinning	.686	1.883	3.441	9.872
VI	Corrective	.725	1.743	4.336	10.295
VII	No pruning	1.309	2.469	8.675	10.601
VIII	Thinning	.990	2.113	4.529	9.553
IX	Cutting back	.749	1.109	3.527	9.573
XI	Alternate (pruned in '18 and '20	1.170	2.017	4.841	9.748
XII	No pruning	1.205	2.980	6.474	12.468

lightly pruned were larger in the top and possessed a greater amount of spur bearing wood than trees more heavily pruned. The pruning had produced a strong vegetative growth, but the continuance of the heavy pruning had reduced the number of growing points or new shoots on the tree and dwarfed the tree in size.

THE EFFECT OF PRUNING ON TOTAL LEAF SURFACE

If heavy pruning of the young tree reduces the number of new shoots formed each year, we should expect that pruning would also reduce the leaf surface on that tree. To secure information on this point leaf counts were made during the third growing season on six representative trees in each plot. Each

leaf on the tree was counted. Individual leaves were collected from the terminal growth and spurs, and were measured with a planimeter to obtain the average area per leaf. In this way the total leaf surface per tree could be calculated. In collecting leaves for leaf area measurements, leaves were collected from the same relative position on the branch of each tree. In removing the leaves from the branch the third or fourth leaf back from the terminal that had reached a mature size was taken off and then alternate leaves on every second or third node from this point were removed. Leaves were also removed from the spurs on the two and three year old wood. These were measured with the others and the average size per leaf was obtained in this way. The leaf counts per tree are presented in Table VII. It will be seen that the trees in rows V and IX which have had heavy pruning possessed, on the average, slightly over half as many leaves as the unpruned trees. It will also be noted that there is an increase in the number of leaves per tree where the pruning has not been so severe. Individual leaves on the terminal growth of heavily pruned trees averaged slightly larger than on the short branches of unpruned trees. However the total number of leaves is so much greater on the more lightly pruned trees that the total leaf area per tree is still larger on the trees receiving no pruning. When we consider that it is the foliage of a tree, which with the aid of sunlight, air and raw food from the roots, manufactures the carbohydrates for the use of the entire tree, the dwarfing effect of pruning on the trees in the data just presented is more readily understood. Chandler (3) has shown a very marked dwarfing of growth in a single season in the case of Delicious trees in the nursery, one year from the graft where the

TABLE VII.—LEAF COUNTS OF TREES IN THIRD GROWING SEASON AND AVERAGE LEAF AREA IN SQUARE INCHES

Row		II	V	VI	VII	VIII	IX	XI	XII
Treatment	Tree No.	No pruning	Cutting back and thin'g out	Corrective	No pruning	Thinning	Cutting back	Alternate	No. pruning
No. leaves	5	5358	2105	1789	3605	1939	2871	2642	2865
" "	10	4219	1963	2128	4866	2499	3224	3586	3793
" "	12	3309	1665	2097	3710	2568	1894	2776	3889
" "	13	4225	1796	1448	3175	1977	3166	3400	3748
" "	15	2181	1725	2441	4156	3727	1807	1791	4045
" "	16	3006	1437	2392	5545	2389	2896	2961	4541
Average		3716	1781	2049	4177	2516	2643	2859	3813
Avg. area per leaf in sq in.		2.44	2.43	2.53	2.15	2.24	2.09	2.31	2.31
Avg. leaf area per tree in sq. in.		9067	4329	5184	8980	5636	5523	6604	8808

opening buds were rubbed off the trunk to a height of eighteen inches. The tops were dwarfed 67% and the roots 72% on the pruned trees. The roots of the tree depend entirely upon the leaves for their supply of carbohydrates. On the heavily pruned trees the leaf surface is reduced, thus the reserves of food material which should go to the roots and other parts of the tree are also reduced. Kraus (5) says, "Any pruning practice would certainly mean a decrease in the amount of storage materials actually remaining as a part of the plant and in a large measure, also the future synthesis of such material, so that the relation of nutrients in the plant to those in the soil about it have been profoundly disturbed. That is to say, top pruning, whatever its nature, would decrease particularly the available carbohydrates and other stored substances in relation to the soil moisture and nutrients."

In 1921 leaf counts were again made on representative trees in each plot. Leaves from four unpruned trees and from two trees in each of the other plots were counted. The trees were then in their fifth season's growth in the orchard. The unpruned trees at this time (Table VIII) show that they have increased very markedly in number of leaves since counts were made in

TABLE VIII.—LEAF COUNTS AND LEAF AREAS PER TREE—FIFTH GROWING SEASON, 1921

Row		II	V	VI	VIII	IX	XI
Treatment		Unpruned	Cut back & thinned out	Corrective	Thinning	Cut back	Alternate
Tree No.	No. leaves						
11	" "	15,790	7,520	11,800	10,825	8,060	10,500
13	" "	18,180	8,280	8,850	10,700	8,800	
Avg. area per leaf in sq. in.		3.2*	3.3*	2.9	3.2	2.9	3.0
11	Total areas in sq. in.	50,528*	24,816*	34,220	34,640	23,374	31,500
13		58,176	27,324*	25,665	34,240	25,520	

*Calculated from measurements of 300 twig and spur leaves. All others are measurements of 150 leaves.

1919. The size and number of growing points have increased on the unpruned tree and the leaf area is twice that of the heavily pruned tree. It is true that at this time the number of small leaves on spurs is very great on the unpruned trees. In collecting leaves to measure leaf area this fact was taken into consideration. Approximately two-thirds of the leaves selected for measurement were twig leaves and one-third spur leaves on the unpruned trees. On the pruned trees a larger number were removed from the twigs because these trees did not produce as many spurs at that time. Even with the slight difference in the

average size per leaf in favor of the pruned tree, the unpruned trees totalling twice the number of leaves per tree would have the greatest leaf surface. Trees which had received light pruning, such as thinning only, or corrective pruning, possess a larger leaf surface than trees which have been heavily headed back as has been the case in rows V and IX. It appears, therefore, that at the close of the fifth growing season unpruned trees continue to possess a much larger top than the more heavily pruned trees (Fig. 8).

COMPARISON OF AMOUNTS OF GROWTH RESULTING FROM UNEQUAL CUTTING OF BRANCHES IN THE SAME TREE

Since the leaf surface of the tree is shown to be closely correlated with increase in size of tree, it is of interest to study how pruning in one portion of the tree would affect the growth in that portion, in relation to the rest of the tree which received no pruning. To secure information on this point, one row of trees (Row X) received partial pruning; that is, four branches of about the same size in diameter and length growth were selected. Two of these were pruned back and two were left unpruned. The central leader was also left unpruned. At the end of the growing season measurements of terminal growth and circumference of the main branches were taken. The terminal growth was removed from those trees that were dug, and was weighed. This data is presented in Table IX. The branches that were pruned averaged slightly larger in girth at the time of the first pruning, but by the end of the season they were smaller in girth than those which were not cut back. At the end of the second season, the girth difference was more pronounced and these same branches which were not cut back, averaged 34% greater girth than branches cut back. The new shoots arising from the branches which were cut back were longer and of greater diameter. However, the new wood produced did not equal in amount that which was cut away. Hence the branches cut back were dwarfed in size in comparison with those not cut

TABLE IX.—GROWTH MADE BY PRUNED AND UNPRUNED LIMBS ON THE SAME TREES, 1917, EXPRESSED IN INCHES

Treatment	No. Limbs	Average Circumf'nce			Total gain	Average Total Length Growth				
		1916	1917	1918		Before pruning 1917	After pruning 1917	Total length 1917	Length gain	Wt. of twig growth in Gr.
Pruned	39	.90	1.10	1.22	.32	30.5	7.2	20.4	13.2	6.0
Unpruned	40	.86	1.18	1.64	.78	30.6	30.6	38.5	7.9	3.2

Fig. 8. Trees shown in Figure 6 at the beginning of the sixth season, 1922. Note the satisfactory length growth of trees having little or no heading back (B) and (C).

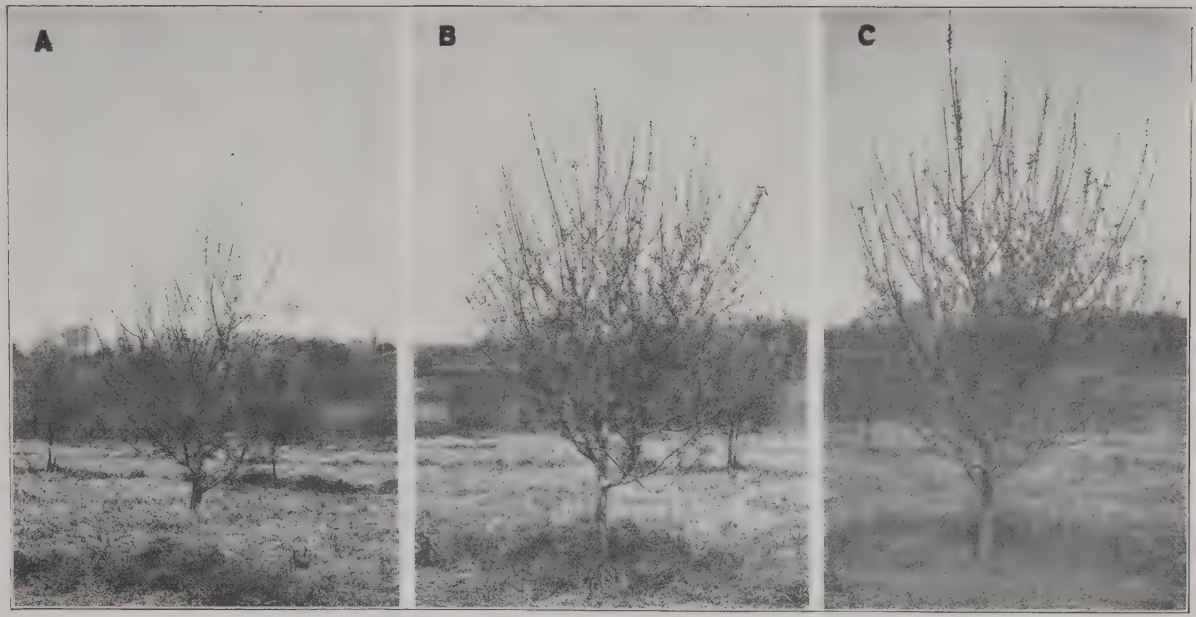

Fig. 9. Trees shown in Figure 3 after pruning, 1922. Note the relative size of the five-year-old trees and the amount of bearing wood in (B) and (C).

back (Fig. 10). The measurements of the new shoot growth produced in the second season, 1918, is given in Table X. It will be noted that in every case the limbs which were not cut back increased markedly in diameter and total shoot growth over limbs which were pruned back. The length growth per shoot was longer on the pruned branches but the unpruned branches produced over three times as many shoots per branch and the total length growth is therefore greater.

Fig. 10. A branch may be dwarfed in total growth in relation to the growth of an adjacent branch by pruning. Scaffold branch 1 was cut back and 2 was left unpruned.

It has often been said that cutting back of the branches will make them more stocky. If diameter growth of the branch is taken as a measure of stockiness, then the reverse of the above statement is more in agreement with these facts, and it is the more lightly pruned branch that is stocky. Magness (6) has shown by experiments in defoliation that plant food is used by the tree in the formation of new growth, near the point where it is manufactured. A reduction in the number of buds on a branch that would give rise to leaves, by pruning, would undoubtedly decrease the available food supply for that area of the tree.

A reduction in the number of leaves following pruning back of branches in two consecutive seasons is shown in Table XI.

It seems, therefore, that pruning in one portion of the tree or on one branch has little influence on the growth response of adjacent branches. Thus heavy pruning of an individual branch brings about a dwarfing effect on that branch, similar to that resulting from heavy pruning of the entire tree. In the former case it would probably be more marked, particularly so if the same branch were pruned heavily for more than one year.

TABLE X.—GROWTH MADE BY PRUNED AND UNPRUNED LIMBS, 1918

Average Girth in Inches				Total Annual Growth					
				Unpruned			Pruned		
Tree	Unpruned	Pruned	Gain over pruned	Total length inches	No. growing shoots	Avg. length per shoot	Total length inches	No. growing shoots	Avg. length per shoot
1	1.53	1.16	.37	142.1	24	5.9	59.0	8	7.4
2	1.88	1.39	.49	178.9	40	4.4	102.3	12	8.5
3	1.97	1.29	.68	248.0	39	6.4	119.0	8	15.0
4	1.65*	1.26	.39	87.8*	16	5.5	27.9*	4	6.9
5	1.60	1.06	.54	133.8	36	3.7	52.7	11	4.8
6	1.49	1.30	.19	159.0	40	4.0	116.1	10	11.5
7	1.65	1.26	.39	205.5	38	5.4	120.8	11	10.9
17	----	----	---	228.3	33	7.2	151.1	11	13.4
18	----	----	---	165.3	25	6.6	130.7	8	16.3

*One limb only.

TABLE XI.—NUMBER OF LEAVES ON PRUNED AND UNPRUNED BRANCHES

Tree No.	Treatment	No. leaves
12	2 pruned limbs	229
	2 unpruned limbs	1670
14	2 pruned limbs	376
	2 unpruned limbs	1216
15	2 pruned limbs	525
	2 unpruned limbs	1020
16	2 pruned limbs	742
	2 unpruned limbs	1308

In pruning and training the young tree, this growth principle should be kept in mind. The weak crotch often resulting from two equally strong branches of the same length, whether they are scaffold branches or secondary branches arising from them, may be corrected by pruning one branch more severely than the other. The heavily pruned branch will make less growth resulting in unequal growth or increase of tissue near the crotch. One of the evils of the open head type of tree is breaking down in the crotch. Not all open head trees have weak crotches but trees trained to this system are often started with many branches arising close together which grow at an equal rate and result in breakage under a heavy strain.

THE EFFECT OF PRUNING ON SPUR PRODUCTION

The unpruned trees which have been shown to possess a larger top and leaf surface than heavily pruned trees, began in the fifth year to show a greater number of spurs on the scaffold limbs, short twig growths and wood older than one year. Spurs had not formed as abundantly on trees that had been cut back each year. This fact has been observed by Gardner (4) in Oregon and Tufts (7) in California working with apple, where the decrease in the number of spurs followed an increase in severity of pruning. Since these spurs are the basis of fruit bud formation and fruit production we begin to have evidence of the effects of heavy pruning on earliness of fruit bearing. In 1920 a few blossoms and fruits were produced on two unpruned trees. This was in the beginning of the fourth growing season. In the spring of 1921 blossom buds began showing in greater numbers on the young trees. The bloom was very abundant on all unpruned trees, fairly abundant on lightly pruned trees (Rows VI, VIII and XI), and very scattering on the heavy pruned trees (Rows V and IX). A severe freeze in late March when the buds were well advanced, killed all of the flower buds. In order to have a record of the fruiting condition of the trees, all blossom buds on each tree were counted. It is rather doubtful if all of these would have borne fruit but a count of the blossom buds at this time gives us information on the spur behavior of those trees that were in a fruiting condition. These data are given in Table XII. It will be observed that twenty of the twenty-three unpruned trees or 87% showed blossom buds ranging in number from 1 to 435 per tree. Ten of the twenty lightly pruned trees or 50% showed blossom buds ranging in number from 1 to 251 per tree. Four of the sixteen heavily pruned trees or 25% showed blossom buds and of these there was only one bud per tree. It is evident that the unpruned and lightly pruned trees which have been making as satisfactory annual terminal growth as the more heavily pruned trees are now settling into a bearing habit of growth, that is, there is probably now accumulating reserves of food material, carbohydrates, which are necessary for the formation of fruit buds.

THE EFFECT OF PRUNING ON YIELD OF FRUIT

In 1922, the sixth season of growth, blossom buds were more numerous than in the previous season. The buds were not counted but the fruits produced by each tree were counted and weighed at harvest time. The yield per tree is given in Table XIII.

All unpruned trees produced fruit in 1922. The 23 unpruned trees excluding those in the buffer rows produced a total of 151 lbs. of fruit or about 6.6 lbs. per tree. The 20 lightly pruned trees also produced fruit totaling 111 lbs. or 5.6 lbs. per tree. Twelve of the 15 heavily pruned trees that were cut back or cut back and thinned out produced a total of 15.75 lbs. of fruit,

or a little over a pound per tree. A great deal of the fruit produced by the heavily pruned trees was from auxillary buds. The same was true in the case of lightly pruned trees. The largest amount of fruit produced on the unpruned trees was from spurs. These data on production, while as yet very meager, are strongly indicative of the fact that heavy pruning has delayed the bearing on trees of this age. The differences are not so great between

TABLE XII.—NUMBER OF BLOSSOM BUDS—MARCH 31, 1921,—TREES 4 YEARS OLD

Row	I	II	V	VI	VII	VIII	IX	XI	XII	XIII
Tree 1	42	7	0	0	6	--	--	48	9	--
Tree 3	27	20	0	0	0	0	0	0	21	0
Tree 5	18	88	0	--	0	-	0	0	2	19
Tree 7	43	273	1	151	1	--	1	0	0	90
Tree 9	305	30	0	--	--	11	0	6	38	1140
Tree 11	60	435	0	0	46	0	0	24	1	0
Tree 13	--	42	0	15	3	2	1	1	12	103
Tree 15	4	6	0	0	35	251	0	32	48	60

TABLE XIII—PRODUCTION OF FRUITS 1922 (6-YEAR-OLD TREES)

Row	I	II	V	VI	VII	VIII	IX	XI	XII	XIII
Tree 1	52	13	4	23	13	--	--	27	3	--
Tree 3	17	63	0	39	36	68	9	14	23	6
Tree 5	34	112	1	--	25	--	8	23	31	43
Tree 7	22	84	0	78	13	--	3	7	8	50
Tree 9	29	57	1	--	--	43	10	17	24	184
Tree 11	41	77	5	1	47	68	1	35	8	3
Tree 13	--	49	6	35	22	39	2	5	27	17
Tree 15	6	34	1	6	29	51	0	24	21	41
Avg. No. per tree	28.7	61	2.2	30	26.4	53	4.7	19	18	49.1
Weight of Fruit Harvested										
Total Weight	45.0	98.5	7.0	37.5	25.5	48.5	8.75	26.75	27.0	65.93
Avg. lbs. per tree	6.43	12.3	.88	6.25	3.64	9.70	1.09	3.34	3.37	9.41

the lightly pruned and unpruned trees though it is noticeable that the heaviest yielding trees are those which have received no pruning. Since the unpruned and lightly pruned trees which

are now making terminal length growths comparable to the pruned trees, are larger and possess a greater number of fruit spurs than the more heavily pruned trees, these facts would strongly suggest that these trees will probably show greater differences in yield in the next few seasons, other factors being equal and favorable.

ANNUAL GIRTH GAINS, 1917-1922

After the removal of the last of the alternate trees in each row for growth studies in 1920, eight trees remained in each plot. In a few of these plots, trees had to be discarded because of certain weaknesses. The growth made by the trees remaining is given in Table XIV for the years 1917-1922. It was from these trees that the data just presented on bud counts and production were taken.

It has been pointed out in preceding tables that in general the greatest terminal growth was made during the first year by trees that had been rather heavily cut back at planting time. After the first year all unpruned or lightly pruned rows have made consistently larger increases in girth than trees heavily

TABLE XIV.—ANNUAL INCREASE IN TRUNK GIRTH IN INCHES, 1917-1922

Row	Treatment	No. Trees	1917	1918	1919	1920	1921	1922	Total Gain	Circumference 1916	Circumference 1922
I	No pruning	7	.27	1.20	1.58	1.55	2.53	2.24	9.36	2.40	11.76
II	No pruning	8	.33	1.11	1.79	1.51	2.43	2.09	9.26	2.48	11.74
V	Cutting back and thinning	8	.34	.71	1.00	1.18	2.09	1.97	7.29	2.49	9.78
VI	Corrective	6	.37	.88	1.44	1.62	2.19	2.32	8.82	2.35	11.17
VII	No pruning	7	.45	.99	1.72	1.56	2.30	2.15	9.17	2.24	11.41
VIII	Thinning	5	.32	.85	1.68	1.60	2.54	2.35	9.34	2.45	11.79
IX	Cutting back	7	.26	.75	1.12	1.22	2.06	1.78	7.21	2.35	9.56
XI	Alternate	8	.23	.64	1.33	1.56	2.14	2.06	7.96	2.43	10.39
XII	No pruning	8	.16	.83	1.48	1.46	2.42	2.31	8.67	2.40	11.07
XIII	No pruning	6	.24	1.00	1.52	1.73	2.65	2.12	9.32	2.48	11.79

pruned. Rows V and IX, the heavy pruned rows, have been quite uniform in this annual increase in girth. It will also be noted that after the year 1919, when pruning on rows VI and VIII became less severe, these trees began to make circumference increases comparable to the unpruned trees and by 1922 were nearly as large. At this time, however, we must take into consideration that the unpruned trees were showing a large number of fruit spurs and began to produce fruits. This condition would be expected to slow up growth on trees passing from a vegetative to a fruitful state.

Fig. 11. Trees shown in Figure 9 in the summer of the sixth season in the orchard. Trees receiving light pruning, as illustrated by (B) and (C) produced considerably more fruit than (A).

At the close of the sixth year for these trees, it will be observed from Table XIV and the illustrations shown in Fig. 11, that in this experiment light pruning for the variety Grimes has produced not only a tree with as good form and mechanical strength of scaffold branches as where heavy pruning was given, but also a larger tree that is coming into bearing earlier. In fact individual trees of this variety in the experiment which have had no pruning since they were planted in the orchard and have been permitted to shape themselves, are superior in size and form to some trees which have had pruning every year since they were planted. It has been the observation of the authors as well as the experience of growers in this state that this variety is not difficult to train. It is an upright grower and the branches can be trained to a desired form with little heading back during the early years of the life of the tree.

An unpruned Stayman, Delicious or Jonathan tree which has a different growth habit from Grimes, would no doubt have presented a more serious problem, if left unpruned for five or six years. Experiments are now being conducted by the Purdue Agricultural Experiment Station on the training of the more important varieties grown in Indiana, to determine the amount of pruning necessary to properly train such varieties during their early life.

TYPE OF PRUNING AS INFLUENCING GROWTH RESPONSE

The data presented up to this point have dealt largely with the effects of the varying amounts of pruning on the size of the tree and earliness of bearing. The response of the trees in this experiment to the manner in which they were pruned is of interest. The response in growth following the cutting back of a branch is well known. The new growth that arises will be longest near the point where the cut was made. On the contrary when an entire branch is removed from a young tree, by thinning, usually no new growth arises from that point unless a large amount of wood is removed. This is illustrated in Fig. 12.

Moderate Cutting Back and Thinning Versus Thinning Only.—Row VI which had what has been termed corrective pruning and row VIII which had thinning only, were the more lightly pruned trees in this experiment. There was not a great deal of difference in the weight of wood removed from the trees under these systems of pruning. However a greater number of branches were removed under the corrective system. Cutting back of the terminal growth under this system removed a larger number of active buds. Much of the new growth resulting from these cuts formed a dense top and required thinning out. Consequently, the pruning under this system was heavier and reduced the total growth more than thinning only. The thinned trees were more upright and open than those receiving the moderate cutting back and thinning out and in the sixth season produced more fruit buds and fruits.

Heading Back Versus Heading Back and Thinning.—The trees in Row IX which had heading back only and those in Row V having heading back and thinning, had all of the terminal growth cut back. In the case of row IX none of the resulting new growth was removed. This gave a very dense hedge-growth type of tree. It was included in this experiment not for its practicability as a system of training, but to study the response to this treatment. The cutting back reduced the total growth but did not reduce the number of growing points or new shoots to the extent that heading back and thinning out did. Thus while under this system, the leaf surface was greater and the tree larger, the tree possessed few fruit buds in the center of the tree where the growth was densely shaded. A much better type of tree was produced where heavy thinning out accompanied heavy heading.

In starting the head of the young tree if heavy heading of the scaffold branches is followed after the first year, and this was very noticeable on all Grimes trees in the experiment, much of the growth will arise near the head or center of the tree, causing it to be dense and requiring thinning out. This cutting back of the branches and the removal of many laterals on them, pro-

Fig. 12. The tree on the left has had thinning only. The one on the right cutting back and thinning out. The new growth is distributed on the thinned tree but is most vigorous near the points of cutting on the tree headed back. A two-year-old Grimes.

duces a scaffold limb that is more or less "crotchy", in contrast to the smoother and straighter limb that has not been so heavily headed back. Undoubtedly, it is this appearance that has given rise to the expression that heavy heading back causes greater "stockiness" of the limb. The growth data presented in Tables IX and X show that such is not the case. Furthermore, it has not been observed in this experiment that this type of growth secured on the heavily cut back limb is necessary to insure mechanical strength in the frame-work of the tree.

Pruning in Alternate Years.—The trees in this experiment that have received moderately heavy pruning in alternate years, have on the whole made greater total growth than trees receiving the same degree of pruning every year. Thus the amount of wood removed by heading back and thinning out in alternate years was not as great in the total and the roots and tops were not reduced in growth to the extent that heavy annual heading back occasioned.

PRUNING TO SECURE A DEFINITE FORM AS IT AFFECTS THE EARLY GROWTH AND DEVELOPMENT OF THE TREE

The data and discussion on pruning in the preceding pages have dealt with the behavior of trees trained to one system when varying amounts of wood were removed. In an experiment begun on the Experiment Station Farm at Bedford, Indiana, in 1916, trees were trained to three systems, namely central leader, open head and natural form. The amount of wood removed depended upon the manner in which the trees were trained. The varieties used were Winesap and Grimes. The trees were two years old and were uniformly selected for all plots. Data were taken on yearly circumference increase in trunk growth and production of fruit.

In addition to the pruning treatment, the soil treatment was varied. One-half of each plot of trees was in grass and the other half was in cultivation. The pruning treatments were duplicated over this area.

Under the natural system the trees were permitted largely to shape themselves. Crossing and crowding branches where they rubbed on other branches were removed, but little cutting back was given. Some trees of the Grimes variety, under this system, assumed the Central leader type while others went more to the open head type. In the Winesaps under this system, the tendency was for the Central leader to predominate.

The trees trained to the Central leader type were pruned so as to make both varieties conform to this system of training. In addition to the pruning, to secure this form, cutting back of the terminal growth for the first three years was done.

In the open head trees the central limb was removed at planting and the scaffold limbs were cut back. The pruning

given was that necessary to train a tree to this form. The new growth on the scaffold branches was shortened one-third to one-half during the first three years.

The weight of wood removed annually in pruning to these systems is given in Table XV.

TABLE XV.—WEIGHT OF WOOD IN POUNDS. REMOVED BY PRUNING

		1916*	1917*	1918*	1919		1920		1921	
Treatment					Tillage	Sod	Tillage	Sod	Tillage	Sod
Natural Form	Grimes	1.1	2.7	8.3	2.0	1.4	2.25	.62	2.7	.19
	Winesap				2.1	.6	1.25	.37	2.4	.37
Central Leader	Winesap	2.8	4.7	8.5	5.1	1.4	2.75	.75	2.1	.12
	Grimes				5.1	1.4	2.37	.50	2.8	.43
Open Head	Grimes	3.7	5.9	9.1	6.0	1.4	4.25	1.0	3.1	.56
	Winesap				3.3	2.0	2.62	1.0	0.6	.25
Natural Form	Winesap	1.2	3.5	8.0	1.0	1.3	.87	.50	1.0	.19
	Grimes				1.2	.9	2.37	.37	1.2	.06
Central Leader	Grimes	2.8	4.5	7.8	4.2	.8	3.25	1.0	2.5	.06
	Winesap				2.1	.4	2.25	.50	.9	.12
Open Head	Winesap	3.6	4.5	7.9	3.5	.2	3.50	1.25	8.4	1.0
	Grimes				4.1	1.4	2.50	.75	4.8	1.2
Natural Form	Grimes	1.4	3.0	9.4	4.5	.5	2.75	.12	1.0	.00
	Winesap				1.9	.2	2.25	.06	6.0	.12

*Note—For the first three years the total weight of wood removed for both varieties is given together for the 20 trees in each plot. After 1918 the weights of prunings are separated for variety and soil treatment.

The growth made by the trees, as measured by the yearly increase in trunk circumference is given in Table XVI.

It will be noted that the trees which were trained to the natural form have made the greatest growth. Trees under this system have had nearly as large an amount of wood removed as trees under the other systems, when measured by the weight of the prunings. However, many of these were entire branches that were removed by thinning, but since there was no cutting back of the terminal growth there were fewer branches removed than with the other systems of training and in this respect, the pruning was therefore lighter. Under the natural form some of the crowding branches were left in during the first few years. Later they were removed. It will also be noted that the growth made by trees trained to the central leader system is greater than that of trees trained to the open head. This is undoubtedly due to the fact that a greater amount of wood was removed from the trees in securing this type of tree than was required to maintain the central leader.

TABLE XVI.—AVERAGE ANNUAL INCREASE IN TRUNK GIRTH IN INCHES

Plot and Variety	Treatment	No. Trees	1916	1917	1918	1919	Total Gain	Circumference 1916	Circumference 1919
A Grimes	Natural Form*	4	.82	1.14	1.10	1.23	4.29	2.15	6.43
Grimes	Natural Form†	5	.56	.81	.56	.65	2.58	2.00	4.58
Winesap	Natural Form*	4	.74	1.33	1.30	1.26	4.69	2.17	6.87
Winesap	Natural Form†	5	.47	.73	.80	.72	2.71	2.02	4.74
B Winesap	Central Leader*	4	.62	1.05	1.12	.95	3.75	2.20	5.95
Winesap	Central Leader†	5	.29	.46	.45	.27	1.47	2.11	3.58
Grimes	Central Leader*	3	.87	1.00	1.19	.98	4.05	2.01	6.06
Grimes	Central Leader†	5	.64	.60	.34	.32	1.86	1.92	3.78
C Grimes	Open Head*	4	.98	.93	.91	.90	3.72	2.02	5.75
Grimes	Open Head†	5	.55	.48	.29	.18	1.50	2.01	3.51
Winesap	Open Head*	4	.60	.94	.96	.87	3.36	2.07	5.43
Winesap	Open Head†	5	.37	.64	.46	.41	1.89	2.13	4.03
D Winesap	Natural Form*	4	.74	1.03	1.12	1.38	4.32	2.05	6.37
Winesap	Natural Form†	5	.46	.79	.79	.65	2.69	2.04	4.74
Grimes	Natural Form*	5	1.01	1.10	1.18	1.17	4.46	2.04	6.49
Grimes	Natural Form†	5	.72	.62	.57	.46	2.37	2.00	4.37
E Grimes	Central Leader*	5	.85	.88	1.04	1.01	3.78	2.06	5.84
Grimes	Central Leader†	5	.56	.57	.51	.44	2.08	1.94	4.01
Winesap	Central Leader*	5	.60	.93	.83	1.12	3.48	2.06	5.55
Winesap	Central Leader†	5	.40	.39	.36	.23	1.38	1.97	3.35
F Grimes	Open Head*	5	.56	.67	.86	.79	2.88	2.12	5.00
Winesap	Open Head†	5	.29	.73	.44	.33	1.79	2.04	3.83
Grimes	Open Head*	5	.81	.65	.85	.65	2.95	2.09	5.04
Grimes	Open Head†	5	.69	.50	.42	.27	1.88	2.01	3.90
G Grimes	Natural Form*	5	.92	1.18	1.28	1.38	4.57	1.98	6.74
Grimes	Natural Form†	5	.70	.67	.51	.37	2.25	1.91	4.14
Winesap	Nauratl Form*	5	.76	1.25	1.26	1.42	4.70	2.13	6.82
Winesap	Natural Form†	5	.33	.55	.24	.58	1.99	2.10	4.09

*Cultivation.
†Sod.

Comparing the two varieties—Grimes and Winesap, in their response to the pruning treatment, Winesap was reduced more in total growth than Grimes. Thus at the end of the first four years in the orchard the average girth gain with Grimes trees trained to the natural form was 13% more than the same variety trained to the central leader and cut back, and 33% more than trees trained to the open-head type and cut back. For Winesap pruned in the same manner, the natural form tree showed 26% greater girth grains than the central leader cut-back trees and 46% more than open-head cut-back trees.

It has been mentioned that Grimes is not a difficult tree to train during its early life. Winesap on the other hand, often develops many branches in the young tree which interfere if not removed. Furthermore, cutting back this variety heavily results in a dense shoot growth in the top of the tree which must be thinned out. The cutting would, therefore, be heavy where this variety was trained to the open-head. We would expect then, that if Winesap were pruned more heavily than Grimes, that a difference in the amount of growth, such as that noted, would be observed with these varieties.

THE INFLUENCE OF CULTURAL TREATMENT ON THE GROWTH OF TREES SIMILARLY PRUNED.

In the experiment one-half of each plot trained to a definite system was left in cultivation with cover crop and the other half was left in sod. It will be noted from Table XVI that the soil treatment has had a marked influence on the growth of the trees, which was greater than that caused by the pruning which the trees received. It is interesting to note that trees which were most lightly pruned, were the largest both in cultivation and in sod. Trees in sod, trained to the natural system, but not cut back, were about 85% smaller in girth than trees similarly treated but receiving cultivation. Trees in sod, cut back, and trained to the open head or central leader type were over 100% smaller in girth than trees in cultivation.

It has been shown by data collected in the experiment where trees were dug from the soil, that heavy pruning has reduced the total growth, but in this experiment there are other factors that have had a greater dwarfing effect than the pruning. In this instance the dwarfing is unquestionably due to the soil treatment. No attempt was made to conserve moisture or to increase the nitrate nitrogen content of the soil with nitrogenous fertilizers.

The data presented in this experiment, cover the first four years of the life of the tree in the orchard. After that time little pruning was given to the trees which had been headed back during that period. The trees produced no fruit until the seventh year. A fairly heavy bloom in the sixth year was killed by a freeze. The fruit produced in 1922 was on the variety Winesap. The amount of fruit (Table XVII) is not very great and is indicative only of the effects of pruning to secure a given form of tree on earliness of bearing.

It will be noted that the trees which were the more lightly pruned, produced the largest amount of fruit. The open head cut-back trees from which the greatest amount of wood was removed, did not fruit. It was evident at blooming time that the trees which had been cut back, did not possess a large number of blossoming spurs. The spurs did not form as abundantly on those trees that were cut back, and although the trees had received little pruning during the last two years, they were not in the fruiting condition of the more lightly pruned trees.

TABLE XVII.—PRODUCTION OF FRUIT IN 1922

TREATMENT	No. of Trees	Total pounds of fruit	
		Cultivation	Sod
Natural form, light pruning	13	143.0	39.0
Central leader, cut back	9	22.5	0.0
Open head, cut back	9	0.0	0.0

EXPERIMENTS AT LAUREL, INDIANA

At Laurel, Indiana, an experiment in pruning was begun in 1912. The variety was Grimes. The trees were trained to the open head and central leader forms. The trees received light pruning, including thinning, in comparison with heading back and thinning. The trees began to bear in 1915. The yield of fruit from these trees for the years in which there was a crop is given in Table XVIII.

Since there are only six trees to a plot, and without considering other measurements of growth response for these trees, these yield data are considered only as supplementary to the data just presented. The total yield of fruit over the six year period 1915-1921 was greatest on the more lightly pruned trees. It is also noticeable that these young trees trained to the central leader type produced more fruit than trees of the same age trained to the open head. However, with the lightly pruned trees this difference in total yield is not very great. This would be expected with a variety like Grimes, which, with little pruning after the first few years, could be trained either to an open-head or central leader.

TABLE XVIII.—YIELD OF FRUIT IN POUNDS AT LAUREL, INDIANA

Treatment	No. Trees	1915	1916	1918	1919	1920	1921	Total
Central leader, cutting back	6	3.2	45.0	15.74	1.18	629.75	916.50	1611.39
Open head, cutting back	6	0.0	22.3	26.25	7.75	247.44	742.00	1045.74
Central leader, light pruning	6	7.0	39.3	53.93	4.19	1215.50	686.50	2006.42
Open head, light pruning	6	1.0	40.0	61.37	10.87	1155.00	653.50	1921.74

It should not be understood from this discussion that the central leader or modified central leader type of tree is the most satisfactory form from the standpoint of production or that pro-

duction is decreased in the open head type of tree as such. These experiments have not gone far enough to determine the best system of training under all conditions. The important fact is the effect of the removal of wood from the tree, incident to securing a desired form on its growth and early fruitfulness. It does not appear that it would be a wise practice to prune a young tree heavily to obtain a certain form, and thus postpone the time of early fruitfulness, when a tree just as satisfactory in form could be secured with less pruning.

GENERAL CONSIDERATIONS

The data presented in this bulletin, covering a period of six years, have shown that heavy pruning of young trees has dwarfed the total growth and has postponed the time of fruitfulness. Similar results have been reported from California (7), West Virginia (1) and New York (3). Pickering (2) has shown similar results with the dwarf trees in the climate of England. In the light of these results, it is worth while to consider in a general way some pruning recommendations that may be employed by Indiana growers for young trees.

It should not be understood that the results of pruning as presented here, suggest that no pruning of young trees is recommended. The cutting away of any portion of the tree during the first year is primarily for the purpose of getting the tree established and selecting a frame-work of scaffold branches that will support a heavy crop of fruit. Not all branches that are on the tree as it comes from the nursery will be retained. If it is a two-year-old tree, three to five branches should be selected so as to be well distributed about the trunk. No branch that is to be left for a scaffold limb should be directly above another branch, thus crowding the lower branch as it increases in size. One of the branches left, preferably the upper or central one should be left longer than the others. It is a safe practice to cut these back at planting time. If not enough scaffold branches can be selected the first year, the remainder of the scaffold branches can be completed in the second year. One year trees should be headed back to a height of twenty-four to thirty inches for starting a new head.

Pruning in the second and third years will not depend on any set rule. Under the conditions of the experiment at Lafayette where the terminal growth was not over twenty to twenty-four inches in the second year, strong scaffold branches were secured without any heading back. On strong soils and where seasonal conditions favor a length growth of three to four feet on two and three year old trees some winter heading back is probably desirable. Pinching shoots that have made length growths of twenty to twenty-four inches by May or early June in Indiana will help to check growths that may be excessively long and thus cause branching lower down on that shoot. This may also obviate any cutting back the following spring. This pinching, however, will probably not be necessary after the second or third

year in most orchards in Indiana. As the tree increases in size and the number of growing points increase, individual shoot growths will not be as long as to require heading back.

From the third year on, until the tree comes into bearing, little pruning may be required. Small branches growing from the scaffold limbs, even though they cross one another, but do not seriously interfere by rubbing, may be well left in. The more wood that can be left on the trees, the greater will be the number of buds that will open into foliage and thus assist in the growth of the young trees.

It may be necessary with certain varieties like Delicious, Stayman, Winesap, and Jonathan, especially on rich soils, to do a little more thinning and light cutting back than with Grimes, in the early years of the growth of these varieties, largely to secure a good distribution of scaffold branches. With any of these varieties heavy cutting back should be avoided. It has been observed that heavy cutting back of a variety like Delicious may result in strong shoot growths near the cut which often grow at about the same rate and form weak crotches. This causes a very dense growth in the top which will require thinning out the following year. Such cutting back should therefore be avoided. A variety like Grimes may need but little more than a judicious thinning out of the branches until after the tree comes into bearing. The photographs in this bulletin illustrate the excellent type of growth made by Grimes, a variety which can frequently be brought into bearing as a well shaped tree, with practically no pruning after the first year.

SUMMARY

1. This investigation deals with a study of the response of young apple trees to varying amounts and kinds of pruning. It covers the period from the time of setting until the trees come into bearing.

2. Two-year-old trees cut back at time of planting made a larger amount of terminal growth during the first two years than trees not cut back, though the latter were larger at the end of that period.

3. Unpruned trees at the end of four years in the orchard were considerably larger in total weight of tree than trees which had received any amount of pruning.

4. Unpruned trees were 25% larger in girth at the end of the sixth season than trees which had received annual cutting back.

5. Pruned trees which received only light thinning or light thinning with minimum heading back of certain branches were much larger at the end of six years than trees which had received a general heading back each year.

6. Heading back during the first three years had reduced root growth 41% as measured by root weights of pruned and unpruned trees.

7. Leaf counts made during the third and fifth years revealed that unpruned trees possessed twice as many leaves as trees of the same age that received heading back and thinning out each year. The amount of foliage per tree decreased as the severity of pruning increased.

8. A branch may be dwarfed in relation to adjacent branches by heading it back more severely. Weak crotches that may result from the union of equally strong growing branches may be avoided by unequal cutting.

9. Trees that had been lightly pruned possessed a very much greater area of spur bearing wood than trees more heavily pruned.

10. Cutting back of young trees delayed the formation of fruit spurs and fruit buds and thus delayed early fruitfulness.

11. Unpruned trees or lightly pruned trees produced more fruit than trees which had received heavier pruning.

12. Light thinning out of crowding branches through the center of the tree did not delay fruitfulness to the extent that thinning out and cutting back in the top of the tree did.

13. Trees which had a "corrective pruning," that is, light pruning during the first few years to properly space the scaffold branches were better balanced in form than most unpruned trees.

14. Pruning to secure a definite form, which required the removal of a large amount of young shoot growth, reduced fruitfulness.

15. Heavy pruning of slow growing trees dwarfed by improper soil culture did not increase the size of the tree over trees in the same soil that were unpruned.

LITERATURE CITED

1. **Alderman, W. H.; Auchter, E. C.**

   1916 The Apple as Affected by Varying Degrees of Dormant and Seasonal Pruning. West Virginia Univ. Agr. Exp. Sta. Bul. 158:1-56.

2. **Bedford, Duke of, Pickering, S. U.**

   1915 Fifteenth Report of Woburn Experimental Fruit Farm.

3. **Chandler, W. H.**

   1919 Some Results as to the Response of Fruit Trees to Pruning. Proc. of Am. Soc. for Hort. Sci. pp. 88-101.

4. **Gardner, V. R.**

   1916 Pruning Investigations. The Early Summer Pruning of Young Apple Trees. Ore. Agr. Exp. Sta. Bul. 139:3-45.

5. **Kraus, E. J.; Kraybill, H. R.**

   1918 Vegetation and Reproduction with Special Reference to the Tomato. Ore. Agr. Exp. Sta. Bul. 149: 1-90.

6. **Magness, J. R.**

   1917 Pruning Investigations. Second Report. Studies in Fruit Bud Formation. Ore. Agr. Exp. Sta. Bul. 146: 3-27.

7. **Tufts, W. P.**

   1919 Pruning Young Deciduous Fruit Trees. Cal. Agr. Exp. Sta. Bul. 313:113-153.